Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 352

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.

Washington, D. C. PROFESSIONAL PAPER. May 5, 1916

THE CHERRY LEAF-BEETLE,[1] A PERIODICALLY IMPORTANT ENEMY OF CHERRIES.

By R. A. CUSHMAN, *Entomological Assistant*, and DWIGHT ISELY, *Scientific Assistant*, *Deciduous Fruit Insect Investigations.*

CONTENTS.

	Page.		Page.
Introduction	1	Description of stages	6
Food plants	2	Life history	9
Distribution	3	Seasonal-history summary	18
Economic history previous to 1915	3	A predatory enemy	19
The 1915 outbreak	3	Control	19
Feeding habits and destructiveness	5	Bibliography	25

INTRODUCTION.

The sudden appearance of enormous numbers of a small red beetle throughout a wide area in the northeastern United States in the spring of 1915 caused consternation among many of the fruit growers of that region. It attacked the foliage of cherry and peach trees and to some extent the fruit of the former. Its range of greatest destructiveness was in New York, Pennsylvania, and northern West Virginia. This insect is the so-called cherry leaf-beetle (*Galerucella cavicollis* LeC.) (fig. 1), a member of the family Chrysomelidæ, and is closely allied to the imported elm leaf-beetle (*G. luteola* Müller). At the time of its appearance practically nothing was known by fruit growers in regard either to its habits or its control, and comparatively little was known by entomologists. Sporadic outbreaks had occurred in the past, but references to them in entomological literature are brief. Taking advantage of this unusual outbreak, the writers have undertaken to secure as complete data as possible in regard to its natural food plants, its immature stages and

[1] *Galerucella cavicollis* LeConte; order Coleoptera, family Chrysomelidæ.

NOTE.—While this paper was going through the press an account of this insect appeared in the Journal of Agricultural Research under the authorship of Glenn W. Herrick and Robert Matheson of Cornell University.

life history, and the means for its control. The work herein discussed was conducted at North East, Pa., during the season of 1915.

FOOD PLANTS.

In the region covered by the writers' observations the natural food plant of this insect is the pin, fire, or bird cherry (*Prunus pennsylvanica*). (Pl. I; Pl. V, *A* and *B*.) Wild black cherry (*P. serotina*) and chokecherry (*P. virginiana*) are entirely immune from attack, even by the beetles. Among cultivated fruits only sour cherry and peach trees are attacked. Even in the sour cherries those varieties, such as the Early Richmond, which have comparatively thin foliage, are much more seriously injured than the thicker leafed varieties. Sweet cherry and plum, common report to the contrary notwithstanding, are not at all eaten. The beetles have frequently been found on these trees, but never feeding. Color is lent to the belief that they attack plums by the very general prevalence of the shot-hole fungus on these trees, casual observers taking the holes caused by the fungus to be the feeding marks of the beetles.

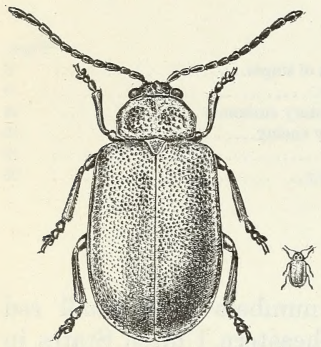


FIG. 1.—Cherry leaf-beetle (*Galerucella cavicollis*): Adult beetle. Much enlarged; natural size at right. (Original.)

All of the foregoing observations in relation to cultivated trees apply to the adult beetle. On only one occasion were larvæ found on anything other than the pin cherry. On August 24 two larvæ were found on leaves of Early Richmond cherry. One of these had attained nearly full growth, while the other was still in the first stage. Neither of them lived to maturity. In the confinement of cages larvæ of the second and third stages fed sparingly on leaves of cultivated cherry, but first-stage larvæ died without feeding. One lot of 57 newly hatched larvæ were fed on peach leaves, but within 6 days all were dead.

From the records just given it appears that, except in the adult stage, this species is not likely ever to become of economic importance.

The beetles are mentioned in literature as having been taken on various other plants, such as apple and chestnut, but these were probably merely strays, although Davis (1896)[1] states definitely that they attacked apple in Michigan. The apple was, however, entirely immune to attack during the present outbreak.

Lugger (1899) mentioned "native plum" as a natural food plant as well as the "fire cherry."

The old idea that *G. rufosanguinea* Say is a Southern form of *cavicollis* together with an obvious mixing of data has led to the inclusion, in literature, of *Ranunculus acris*, a buttercup, among the host plants of *cavicollis*. *G. rufosanguinea* is known to breed on wild azalea.

[1] Dates in parentheses refer to the Bibliography, p. 25.

In a note entitled "Beetles on buttercup and azalea," in answer to a correspondent, Walsh (Pract. Ent., 1866, vol. 2, p. 9) determined *G. rufosanguinea* from *Ranunculus acris* and another beetle from *Azalea nudiflora*. Quite obviously the *G. rufosanguinea* should have been recorded from the azalea. Lintner (1896), quoting Walsh, says: "If the identification of Walsh was correct, it [i. e., *G. cavicollis*] has also been taken in June on buttercup, *Ranunculus acris*, in the vicinity of Albany, N. Y."

DISTRIBUTION.

Galerucella cavicollis is known to occur from Canada and the New England States west to Minnesota, and south along the Appalachians into West Virginia and Virginia. The type specimen is said to have come from North Carolina. It has been taken, according to Smith (1909), at Sea Isle and Anglesea, both localities near the southern point of New Jersey. According to Chittenden (1899), it has also been taken at Vancouver, British Columbia, and in Texas. It quite likely occurs throughout the natural range of its native host plant, *Prunus pennsylvanica*, which, according to Gray,[1] is "Lab. to B. C., S. to Pa., Great L. region, centr. Ia., and along mts. to N. C., Tenn., and Colo." Britton and Brown[2] add Georgia.

ECONOMIC HISTORY PREVIOUS TO 1915.

Economic injury by this beetle was first recorded in 1894 by Davis, who found it feeding on cultivated cherry at Bellaire, Mich. It was again reported the following year from Au Sable Forks, N. Y., by Lintner. In 1897 it was reported as destructive at Traverse City, Mich., by Pettit, and (1898) at Corning, N. Y., by Felt. The next year Chittenden (1899) recorded injury from St. Ignace, Mich., and Spruce Creek and Lebanon, Pa. Injury was observed by Harvey (1901) at Orono, Me., in 1900.

No outbreaks occurring after this time have been specifically recorded in entomological literature, although there are some general references to the beetle. However, economic injury was reported by correspondents to the Bureau of Entomology in 1912 from Newberry and Pontiac, Mich., and in 1914 from Muncy and Williamsport, Pa.

THE 1915 OUTBREAK.

EXTENT OF INJURY.

The 1915 outbreak was probably by far the most injurious that has ever occurred. Complaints regarding this pest were much more numerous and from many more localities than those from all preceding years combined. The beetle, instead of inflicting injury in a few

[1] New Manual of Botany (7th edition). [2] Illustrated Flora of the United States and Canada.

restricted localities, was generally destructive throughout two comparatively large regions; the one, in the Appalachian region, involving the greater part of New York, Pennsylvania, and northern West Virginia; the other in the northern part of lower Michigan, especially in the Grand Traverse region, where cherry growing is very extensive. In regard to the latter region Prof. R. H. Pettit, of the Michigan Agricultural College, writes (in litt.) that during the period of destructiveness by this beetle nearly every mail brought complaints. No complaints were received by the Bureau of Entomology from the territory intervening between these two regions. One of the writers, on June 17 and 18, traveled by trolley through Ohio from Sandusky to Ashtabula, stopping at a number of points between, and no injury by these beetles was noted.

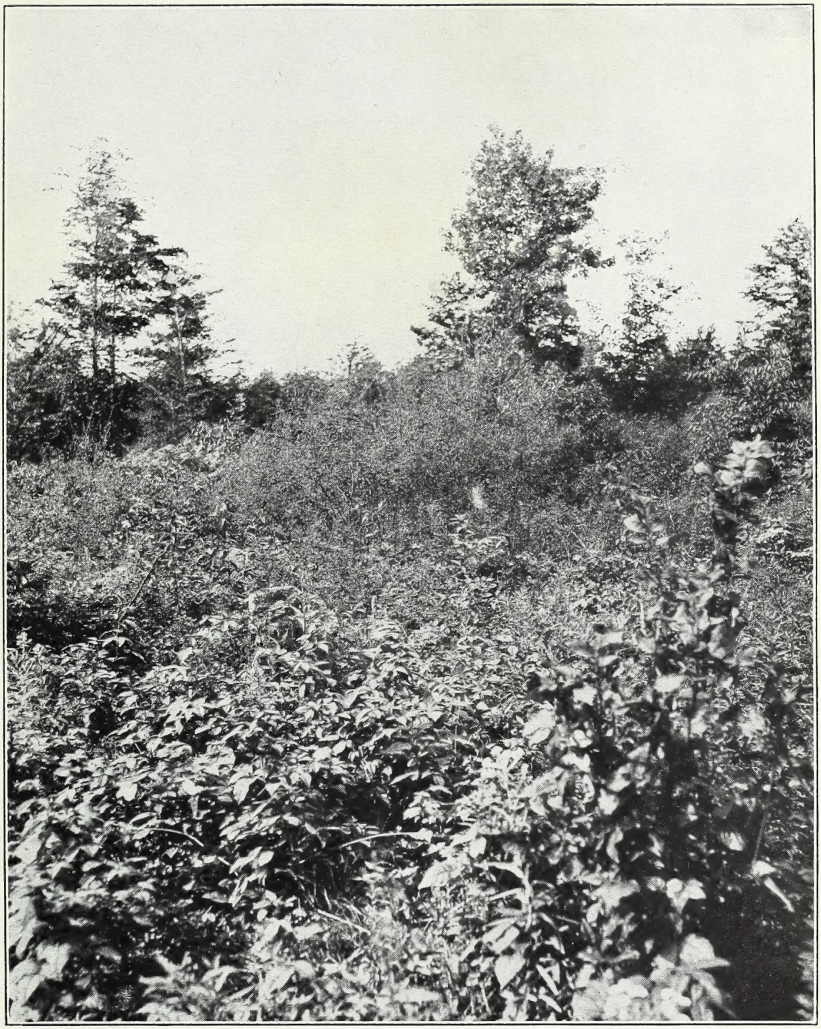
The majority of complaints came in June. However, the beetle was reported from Jamestown, N. Y., as early as May 12, and from Williamsport, Pa., May 21. The general migration to cultivated food plants in northwestern New York and Pennsylvania did not occur until the week of June 7. Farther south, in West Virginia, it occurred about the same time, the first report having been sent June 9.

THE 1915 INVASION OF THE LAKE ERIE GRAPE BELT.

The beetles appeared in the vicinity of North East, Pa., on June 7, literally covering the leaves of the trees attacked. Early in the morning their advent attracted the attention of fruit growers living 3 or 4 miles south of Lake Erie, and by noon they were found in great numbers in orchards near the lake. After this first day of migration the increase was comparatively small, and no increase at all was noticeable in the vicinity at large after June 9, although there was some local shifting of numbers.

During the first few days of the migration stories told by fishermen of the abundance of the beetle on the lake were current; how pieces of wood floating on the water had been covered with them; how they had crowded on black buoys until the color of the buoys had been changed to red; and how the water itself had been full of them. But even after giving these stories the full discount that is generally accorded to stories of like origin, the fact still remains that the migration of great numbers of beetles extended for some distance over the lake. Dead beetles were found in considerable numbers on two of the lake beaches by one of the writers on June 10, when a strong north wind was blowing, and it was reported that they had been washed up in windrows. The occurrence of these beetles in the lake gave rise to the opinion that they had come from Canada.

The actual source of the beetles was to the south of the grape belt, from cut-over forest land grown over by pin cherry. The preceding



TYPICAL BREEDING GROUND OF THE CHERRY LEAF-BEETLE (GALERUCELLA CAVICOLLIS).

A group of pin-cherry bushes stands in the center of the picture. (Original.)

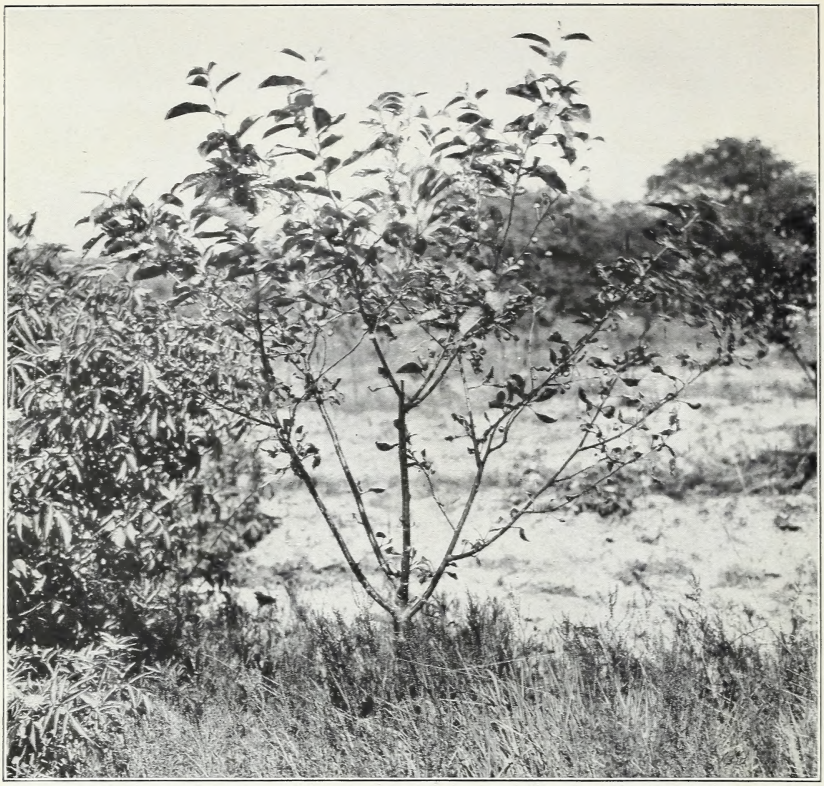
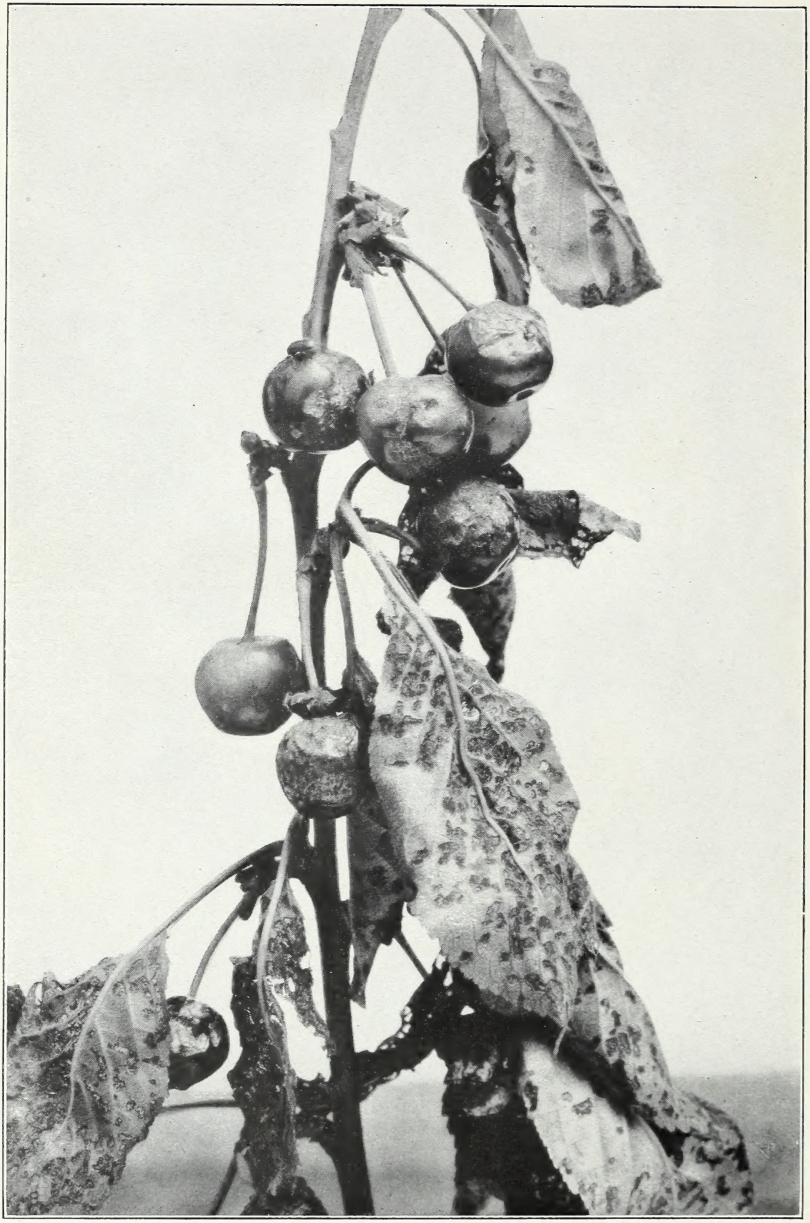


FIG. 1.—COMPARATIVE INJURY TO LOWER AND UPPER BRANCHES. (ORIGINAL.)

FIG. 2.—A YOUNG ORCHARD DEFOLIATED. (ORIGINAL.)

DEFOLIATION BY THE CHERRY LEAF-BEETLE OF YOUNG RICHMOND CHERRY TREES.

INJURY TO FOLIAGE AND FRUIT OF CHERRY BY THE CHERRY LEAF-BEETLE. (ORIGINAL.)



INJURY TO FOLIAGE AND FRUIT OF CHERRY BY THE CHERRY LEAF-BEETLE. (ORIGINAL.)

THE CHERRY LEAF-BEETLE.

Figures *A* and *B* show the effect of feeding of the cherry leaf-beetle on pin cherry. Figures *C* and *D* show beetles feeding on leaves of cultivated cherry. (Original.)

season had undoubtedly been favorable to the development of unusual numbers of these beetles—as much as their native host plant could support. Furthermore, the foliage of the pin cherry was reduced by a freeze on May 27, and perhaps in a part of the range by tent caterpillars also. Similar conditions were probably responsible for the outbreak in Michigan. These conditions induced a migration which was given direction by a strong wind that blew from the southeast and south on June 5, 6, and 7. It is probable that the majority of the beetles had emerged from hibernation and had been feeding for some time before their advent in the grape belt, for an outbreak was reported from Jamestown, N. Y., about 25 miles south of Lake Erie, as early as May 12.

Within a few days after their arrival the numbers of the beetles began to decrease in some orchards, and in two weeks this was general. By the latter part of June practically all had disappeared from the orchards, although a few scattering ones were found as late as early August.

CAUSE OF INCREASE OF BEETLES.

The increased numbers of the cherry leaf-beetle may be attributed to an increase in abundance of its natural food plant, the pin cherry. This tree springs up rapidly along roadsides and in cut-over or fire-swept forest land which has been left uncultivated. Such lands cover wide areas in western Pennsylvania, and furnish ideal breeding conditions for the beetle. A typical view of such a situation is shown in Plate I.

FEEDING HABITS AND DESTRUCTIVENESS.

The adult cherry leaf-beetle feeds almost exclusively on the underside of the leaves of the plants attacked (Pl. V, *C, D*), eating small, irregular holes through the lower epidermis and parenchyma and sometimes through the entire leaf. These holes may join one another or come so close together as to skeletonize the leaf. In a few days after feeding, the upper epidermis thus exposed dries and falls out, and, in case of severe injury, the whole leaf dries, and defoliation ensues. To an extent it feeds also upon the fruit of the cherry, scarring and pitting it. (Pls. III, IV.)

On cold days and at night the beetles crowd on the upper surface of the leaves, and hence have given the impression that they feed there. Occasionally the writers have found beetles feeding on the upper surface of peach leaves, usually those attacked by leaf curl, and once on the upper surface of cherry leaves. The misapprehension in regard to their feeding on plum has been discussed in an earlier paragraph. The shot-hole fungus, responsible for this mistaken belief, also attacks other stone fruits which the beetle attacks, and

caused the impression that the injury by the beetle was greater than really was the case.

The larvæ of all ages feed in a manner similar to the adults, on the under surface, eating through the leaf to the upper epidermis, but leaving that intact. Occasionally a first-stage larva is found feeding on the upper surface, but this occurs only on very young leaves that have not entirely unfolded.

The feeding preference for sickly or injured trees was marked. Such trees were invariably loaded with beetles, while the surrounding trees may have been comparatively free from attack. The foliage on an unhealthy branch was attacked before the rest of the tree. The preference for the foliage on the lower limbs to that of the upper was still more conspicuous, for the lower limbs may have been completely defoliated, while the foliage of the upper limbs was comparatively uninjured. (Pl. II.)

The period of economic injury due to this beetle extended over 14 or 18 days after its first appearance in June. Probably the greater part of the feeding was done during the first three or four days. There was no injury noticeable from the later brood.

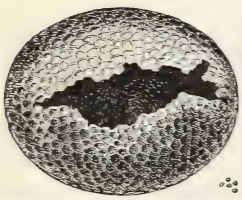


FIG. 2.—The cherry leaf-beetle: Egg. Much enlarged. (Original.)

Severe injury due to this beetle was confined almost entirely to the Early Richmond cherry, especially to young trees. (Pl. II.) In a few young orchards, within four days after the first appearance of the beetles, the foliage on the lower half of the trees was a withered brown, as if it had been burned. In two weeks the trees were almost completely defoliated. On peach and other varieties of cherry trees, although in some instances the feeding appeared quite severe, there was little defoliation.

DESCRIPTION OF STAGES.

THE EGG.

The egg (fig. 2) was first described by Chittenden (1899). It is nearly spherical and bright reddish brown and has the surface deeply pitted with irregularly hexagonal areas. The eggs vary somewhat in size and proportions, but average about 0.75 mm. long by 0.65 mm. in width.

THE LARVA.

Except for the increase in size, all three larval instars are very similar. In the early part of each instar the larva is nearly uniform, very dark olive in color, about three times as long as broad, and with short stout legs. It is broadest at the prothorax, which is about twice as broad as the nearly hemispherical head, and tapers backward to the ninth abdominal segment, which is slightly narrower than the head. Each of the three thoracic and the first eight abdominal segments are more or less conically produced at the sides and bear long bristles extending laterally. Dorsally there are transverse rows of short bristles across the front of the prothorax and double rows across each of

the other thoracic segments, and all abdominal segments except the ninth and tenth. The head is provided with a few scattered long bristles. The ninth abdominal segment is rounded behind and concave above, very heavily chitinized, and with a row of long bristles around the edge. Below it is rather conical, with the very small tenth segment forming the apex of the cone. The latter bears the anus, which is modified to form an auxiliary organ of locomotion. On each side, between the prothoracic and mesothoracic segments, can be seen a small tubercle surrounding the mesothoracic spiracle, and each of the first eight abdominal segments is provided with a pair of spiracles. On each side of the middle the prothorax is irregularly impressed. This concavity persists through all stages.

FIG. 3.—The cherry leaf-beetle: Newly hatched larva. Much enlarged. (Original.)

At full growth (fig. 4) each instar is very much distended, the yellowish skin becomes visible, and the dark color is confined to plates and patches, the head, and the legs. The abdomen is parallel sided and wider than the thorax. The head and ninth abdominal segment, at least above, do not share in this distension, but retain the size originally assumed after the molt. The dorsal surface of the prothorax is covered by a single large, dark-colored plate, flanked on either side by the dark colored, chitinized tips of the lateral prominences. Just below the latter are two small plates partially surrounding the base of the coxa. Ventrally the dark color is confined to a nearly square median patch with a very small oval patch behind it. In the mesothoracic and metathoracic segments the dorsal plate is broken up into two double transverse rows of three plates each, the middle one in each row being much the largest, and transversely elongate. The lateral edges of the dorsum are very heavily chitinized and dark colored. Below the latter are two smaller plates, the anterior one of which on the mesothorax bears the spiracle, the other being the tip of the lateral prominence. Each of the coxæ is partially surrounded above by two small plates as in the prothorax. Ventrally there are three plates, a large transverse anterior one and a pair of small, nearly oval ones posteriorly. The dorsal plate of each of the first eight abdominal segments is similar to that of the mesothorax and of the metathorax, being broken up into two double rows of plates, but on the lateral edge of the dorsum are two very small plates, the posterior one of which bears the spiracle. Beyond these is the chitinized apex of the lateral prominence. Below the color is distributed in a transverse row of five spots. The ninth segment has ventrally a crescent-shaped plate in front of and partially surrounding the very small tenth segment, which bears the anus. The tenth segment is heavily chitinized laterally and posteriorly. (Fig. 5.)

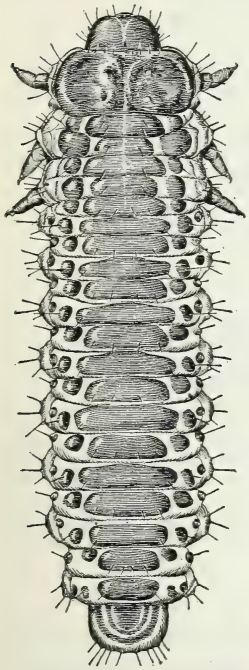


FIG. 4.—The cherry leaf-beetle: Full grown larva. Much enlarged. (Original.)

The newly hatched larva is shown in figure 3. The comparative size of the three larval stages is indicated by figure 6, which shows the heads and ninth abdominal segments drawn to the same scale.

First instar.—The first larval instar (fig. 3) varies with age from 2 to 3 mm. in length with the head 0.38 mm. and the ninth segment 0.36 mm. broad. (Fig. 6, *a*.)

Second instar.—Immediately after the first molt the second instar is about 3 mm. long, and at full growth 4.5 mm. long. The head is 0.57 mm. and the ninth abdominal segment 0.5 mm. broad. (Fig 6, *b*.)

Third instar.—The newly molted larva of the third instar is 4.5 mm. long with the head 0.78 mm. and the ninth segment 0.7 mm. broad. At full growth (fig. 4) it is 7 mm. long and the measurements of head and caudal segment are unchanged. (Fig. 6, *c*.)

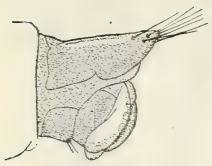


FIG. 5.—The cherry leaf-beetle: Eighth and ninth abdominal segments, lateral view, showing extruded end of alimentary canal used as auxiliary organ of locomotion. Much enlarged. (Original.)

THE PUPA.

The pupa (fig. 7) is slightly less than 5 mm. long, bright yellow, and with a pair of strong curved spines at the apex of the abdomen. The prothorax has the concavity characteristic of all stages of the species. The head has a curved row of four bristles above, the concave side of the curve to the front. On the pronotum are two rows of four bristles each, the anterior one curved to the front and the posterior one to the rear, and in addition a long bristle on each lateral angle and two near the posterior edge. The scutellum and metanotum each have a nearly straight row of four bristles. Each of the abdominal segments, except the last, has a pair of small bristles near the middle, and a single long bristle at each lateral angle. Each femur has a pair of apical bristles. The spiracles of the first five abdominal segments and of the mesothorax are conspicuous from their black color; the outer ends

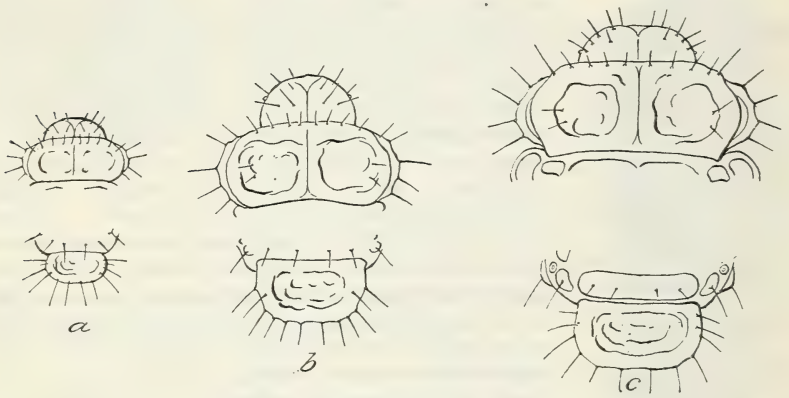


FIG. 6.—The cherry leaf-beetle: Larval heads and caudal segments, showing proportional size in the three instars: *a*, First instar; *b*, second instar; *c*, third instar. Greatly enlarged. (Original.)

of the tracheæ show black through the body wall for a short distance. The spiracles of the sixth and seventh segments are paler.

THE ADULT.

The adult beetle is rather oval in shape, about one-sixth of an inch long by about one-half as broad, and somewhat flattened. It is dull red with black legs and antennæ.

As Le Conte's original description of the species is in Latin, the description given by Horn (1893) is quoted below:

G. cavicollis Lec., Proc. Acad. 1865, p. 216. Oval, narrower in front, subdepressed; color dull red, slightly shining, very sparsely finely pubescent. Antennæ entirely

black. Head red, coarsely punctured, without median depression, frontal tubercles smooth. Thorax nearly twice as wide as long, narrower in front, sides arcuate, or obtusely subangulate, hind angles distinct, base on each side obliquely sinuate, disc feebly convex, a broad depression each side and another along the middle, surface coarsely punctured, more densely in the depressions; scutellum red; elytra broader behind the middle, sides arcuate, margin explanate, humeri distinct, but rounded; sutural angle well marked, but obtuse; disc with coarse and deep punctures not crowded, less deep near the apex, interspaces smooth, shining. Body beneath red, the metasternum often piceous, sparsely finely punctate and finely pubescent. Legs variable in color entirely red to almost entirely piceous. Length .18–.22 inch; 4.5–5.5 mm.

Male.—Claws finely bifid at apex. Last ventral segment broadly emarginate at apex, with a deep triangular depression limited by a sharply elevated line.

Female.—Claws more deeply bifid, the parts more divergent. Last ventral segment with a very slight emargination, in front of which is a slight fovea.

The middle coxæ are absolutely contiguous, the mesosternum is not prolonged between them, except as to the color of the legs no variation has been observed in this species.

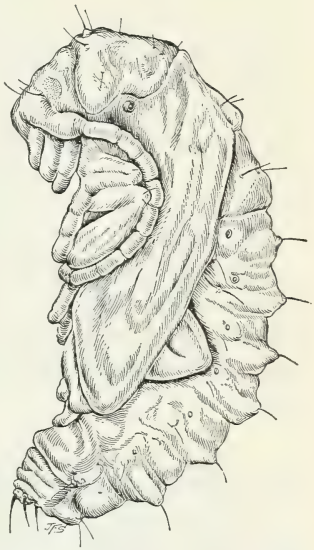


FIG. 7.—The cherry leaf-beetle: Pupa. Much enlarged. (Original.)

LIFE HISTORY.

In the life-history work data were obtained on nearly 600 individuals, almost half of which were carried through their entire development from hatching to emergence of the adult insect. Daily observations were made and recorded, so that all transformations were noted within 24 hours of their occurrence.

It should be noted that the period—August and the first half of September—covered by these observations was one of unusually low temperature and high humidity for the season. In August there was at Erie, 16 miles west of North East, an average daily deficiency in temperature of 2.3° F. and an excess in precipitation over the normal, for the month, of 6.02 inches. In September the temperature was higher, but the precipitation was still abnormally high. The life-history periods shown by this data, therefore, are probably somewhat longer than the normal for the species.

The life-history work was carried on in 1-inch vials, the larvæ being supplied daily with fresh leaves of pin cherry. For pupation about 1½ inches of earth was supplied. For larger lots jelly tumblers were used. Very few of the individuals failed to mature and emerge as beetles.

THE ADULT BEETLE.

Reaching the adult stage in the late summer and early fall, the beetles feed for a few weeks, and then seek out a protected situation in which they pass the winter. According to Pettit (1904) the beetles pass the winter several inches below the surface of the ground. Emerging from hibernation in the spring, they feed again for some time, mate, and the females descend to the base of the trees, where, among the decaying leaves and other vegetable matter, they deposit their eggs. Occasionally they utilize for this purpose accumulations of rubbish in the cavities in the bark of large trees. In such situations eggs have been found as high as 4 feet above the ground.

INCUBATION PERIOD.

No definite data on the incubation period were obtained, but on August 3 and 5 two lots of eggs were collected and placed in vials with the rubbish on which they were deposited. Most of those of August 3 had already hatched, but young larvæ continued to emerge until August 14, 11 days after the collection of the eggs. This lot was collected on the hills about 4 miles back from the lake. The lot of August 5 was collected only about a mile from the lake, and included a much smaller percentage of hatched eggs. This lot continued to produce larvæ until August 18, 13 days after collection. These figures are probably very near to the incubation period for the season of 1915, since Chittenden (1899) records a period of 11 days in 1898 at Washington, D. C.

THE LARVA.

In hatching the larva cuts an irregular slit in one side of the egg. It then ascends the tree, and, feeding on the underside of the leaf, grows very rapidly. During its feeding period it molts twice. In molting the skin splits down the middle line of the thorax, the split extending on to the head, where it divides and extends to each side of the mouth. The head, thorax, and appendages are withdrawn, and the larva secures a hold on the leaf with its feet and crawls out of its old skin, which remains for some time fastened to the leaf.

First instar.—In the course of the life-history work 243 larvæ were carried through the first instar. Of these 79 required 4 days; 140, 5 days; 17, 6 days; 5, 7 days; 1, 10 days; and 1, 11 days. This gives an average period for the first instar of 4.83 days. The first of these hatched on August 5 and the last molted for the first time on August 24, this being the period in which all the data on this instar were obtained. Table I summarizes these data.

TABLE I.—*Period of first larval instar of the cherry leaf-beetle at North East, Pa., 1915.*

Number of individuals.	Duration of first larval instar.
	Days.
79	4
140	5
17	6
5	7
1	10
1	11
243	[1] 4.83

[1] Average.

Second instar.—Data for the duration of the second instar were obtained from observations on 268 larvæ. The period covered by these observations was from August 6, when the earliest first molt took place, to August 29, when the last one molted for the second time. Table II shows the results obtained:

TABLE II.—*Period of second larval instar of the cherry leaf-beetle at North East, Pa., 1915.*

Number of individuals.	Duration of second larval instar.
	Days.
145	3
100	4
18	5
5	6
1	7
269	[1] 3.58

[1] Average.

Third instar.—When the larva becomes full grown it leaves the tree, burrows into the soil for a fraction of an inch, and constructs its pupal cell. That portion of its life between its second molt and its entrance into the ground—that is, the feeding period of this instar—was determined for 349 larvæ, with the results given in Table III. The first of these to molt for the second time did so on August 7, and the last one entered the ground on September 5.

TABLE III.—*Feeding period of third larval instar of the cherry leaf-beetle, North East, Pa., 1915.*

Number of individuals.	Feeding period of third larval instar.
	Days.
64	3
211	4
55	5
8	6
8	7
3	8
349	[1] 4.12

[1] Average.

Total feeding period.—A total of 227 larvæ were carried through the entire feeding period from hatching to entrance into the ground. Table IV contains the data obtained. These data were obtained during the period from August 5, when the first one hatched, to September 5, when the last one entered the ground.

TABLE IV.—*Total feeding period of larvæ of the cherry leaf-beetle, North East, Pa., 1915.*

Number of individuals.	Total feeding period.	Number of individuals.	Total feeding period.
	Days.		*Days.*
3	10	1	16
49	11	2	17
115	12	5	18
36	13	2	20
7	14		
7	15	227	[1] 12.33

[1] Average.

PERIOD IN GROUND.

The pupal cell is nearly spherical and about 5 mm. in diameter. It is from a fourth to a half inch below the surface. Within it the insect passes through the transformations from larva to pupa and from pupa to adult. The larva lies for several days curled up as shown in figure 8 before transforming to the pupa.

FIG. 8.—The cherry leaf-beetle: Prepupal larva. (Original.)

Data on the dates of transformation of the larva are difficult to obtain, since this necessarily involves the breaking up of the pupal cell, and such data as were obtained are based on but few individuals.

Prepupal period.—In a lot of larvæ that entered the ground on August 5 daily examination showed that the first one pupated on August 13, or 8 days later. On the same day 1 pupa was found among larvæ that entered the ground on August 6, giving a prepupal period of 7 days. One out of 3 larvæ that entered the ground on August 7 had pupated 7 days later, on August 14. Larvæ that entered the ground on September 4 and 5, when the weather was much warmer than in August, required only 5 days to pupate.

Pupal period.—In the August lots just mentioned the first transformation to the adult stage took place 9 days after the first pupation, while in the September lots the pupal period was only 7 or 8 days. In a lot which entered the ground on August 22 the first one pupated on September 10, 19 days later. Unfortunately, the prepupal period for these was not determined, but as that period was passed during the very cold days of late August, it was undoubtedly longer than in the earlier and later lots, and the pupal period was probably close to 11 days in length.

Emergence of the adults takes place from a day to several days after transformation.

Total period in ground.—Five hundred and sixty-three individuals were carried through this period of their development, the time required varying from 14 to 28 days, with the greatest emergence on the twenty-second day. Table V gives the data on this point.

TABLE V.—*Total period spent in the ground by stages of the cherry leaf-beetle.*

Number of individuals.	Period in ground.	Number of individuals.	Period in ground.
	Days.		*Days.*
2	14	116	23
1	15	47	24
1	16	62	25
1	17	30	26
9	18	3	27
44	19	1	28
30	20		
68	21	563	[1] 22.36
148	22		

[1] Average.

The males required on the average 0.1 of a day longer than the females, the average for the males being 22.41 days and for the females 22.31 days.

DEVELOPMENTAL PERIOD.

The total developmental period, exclusive of the incubation period, of 218 individuals was obtained. This varied from 31 to 40 days, with the heaviest emergence on the thirty-third and thirty-fourth days. Table VI gives the data obtained.

TABLE VI.—*Total developmental period of the cherry leaf-beetle, exclusive of the incubation period, North East, Pa., 1915.*

Number of individuals.	Developmental period.	Number of individuals.	Developmental period.
	Days.		*Days.*
3	31	2	37
27	32	1	39
67	33	1	40
63	34		
45	35	218	[1] 33.76
9	36		

[1] Average

The males required 33.81 days and the females 33.73 days. Allowing an incubation period of 11 days the total developmental period would be in the neighborhood of 45 days. Table VII gives in more detail all the life-history data obtained.

TABLE VII.—*Developmental period of the cherry leaf-beetle exclusive of the incubation period, North East, Pa., 1915.*

Lot No.	Date hatched.	Date first molt.	Number of individuals.	First stage duration.	Date second molt.	Number of individuals.	Second stage duration.	Date in ground.	Number of individuals.	Feeding period, third stage.	Total feeding period.	Date adults emerged.	Number of—		Period in ground.	Period from hatching to emergence of adults.
													Male.	Female.		
				Days.			*Days.*			*Days.*	*Days.*				*Days.*	*Days.*
2								Aug. 5				Aug. 23	3		18	
												Aug. 24	2	6	19	
												Aug. 28	1		23	
6								Aug. 6				Aug. 24	2		18	
												Aug. 25	9	19	19	
												Aug. 26	3		20	
												Aug. 27	4	4	21	
												Aug. 28	6	8	22	
												Aug. 29	4	4	23	
												Aug. 30	1		24	
9								Aug. 7				Aug. 29	7	12	22	
												Aug. 30	9	14	23	
												Aug. 31	7	2	24	
												Sept. 1	5	4	25	
												Sept. 2	4	8	26	
												Sept. 3		3	27	
												Sept. 4	1		28	
11								Aug. 8				Aug. 26		1	18	
												Aug. 28	2		20	
												Aug. 30	1		22	
												Aug. 31	2	1	23	
												Sept. 1	3	1	24	
												Sept. 2	19	12	25	
												Sept. 3	6	11	26	
17								Aug. 9				Aug. 29	1	1	20	
												Aug. 30	1		20	
												Aug. 31		2	22	
												Sept. 1	2	1	23	
												Sept. 2	6	11	24	
												Sept. 3	12	10	25	
												Sept. 4	1		26	
8					Aug. 7			Aug. 11	23	4		Sept. 2	2	2	22	
												Sept. 3	4	7	23	
												Sept. 4	3	3	24	
								Aug. 12	3	5		Sept. 1	1		20	
												Sept. 4	1		23	
								Aug. 13	1	6		Sept. 3		1	21	
								Aug. 14	1	7		Sept. 5	1		22	

12	.....	.....	.....	.....	Aug. 8	.....	.....	Aug. 11	6	3	.....	Sept. 2	.....	1	22	.....			
												Sept. 3	1	1	23	.....			
												Sept. 4	.....	1	24	.....			
								Aug. 12	24	4	.....	Sept. 3	5	4	22	.....			
												Sept. 4	5	2	23	.....			
												Sept. 5	2	.....	24	.....			
								Aug. 13	11	[1] 5	.....	.....	.....	.....	.....	.....			
								Aug. 14	4	6	.....	Sept. 5	.....	2	22	.....			
												Sept. 6	.....	1	23	.....			
16	.....	.....	.....	.....	Aug. 9	.....	.....	Aug. 13	6	4	.....	Sept. 4	.....	1	22	.....			
												Sept. 5	1	1	23	.....			
								Aug. 14	5	5	.....	Sept. 5	3	1	22	.....			
												Sept. 6	.....	1	23	.....			
								Aug. 16	5	7	.....	Sept. 6	2	1	21	.....			
												Sept. 8	.....	2	23	.....			
3	.....	Aug. 6	.....	.....	Aug. 10	1	4	Aug. 14	1	4	.....	Sept. 7	.....	1	24	.....			
					Aug. 11	1	5	Aug. 15	1	4	.....	Sept. 6	1	.....	22	.....			
4	.....	Aug. 5	.....	.....	Aug. 10	1	5	Aug. 15	1	5	.....	.....	.....	.....	.....	.....			
7	.....	Aug. 7	.....	.....	Aug. 11	8	4	Aug. 14	3	3	.....	Sept. 5	1	2	22	.....			
								Aug. 15	5	4	.....	Sept. 6	.....	1	22	.....			
												Sept. 7	2	1	23	.....			
												Sept. 8	1	.....	24	.....			
					Aug. 12	2	5	Aug. 15	2	3	.....	Sept. 7	1	1	23	.....			
13	.....	Aug. 8	.....	.....	Aug. 12	5	4	Aug. 16	5	4	.....	Sept. 7	2	1	22	.....			
												Sept. 8	.....	1	23	.....			
												Sept. 9	1	.....	24	.....			
					Aug. 13	1	5	Aug. 18	1	5	.....	Sept. 11	1	.....	24	.....			
					Aug. 14	1	6	Aug. 19	1	5	.....	.....	.....	.....	.....	.....			
15	.....	Aug. 9	.....	.....	Aug. 12	2	3	Aug. 16	2	4	.....	Sept. 7	.....	1	22	.....			
												Sept. 8	.....	1	23	.....			
					Aug. 13	5	4	Aug. 16	2	3	.....	Sept. 7	1	.....	22	.....			
												Sept. 8	1	.....	23	.....			
								Aug. 17	1	4	.....	Sept. 9	1	.....	23	.....			
								Aug. 18	2	5	.....	Sept. 9	1	.....	22	.....			
												Sept. 10	.....	1	23	.....			
					Aug. 14	1	5	Aug. 17	1	3	.....	Sept. 8	1	.....	22	.....			
					Aug. 15	3	6	Aug. 19	1	4	.....	Sept. 10	.....	1	22	.....			
								Aug. 21	2	6	.....	Sept. 11	.....	1	21	.....			
												Sept. 12	1	.....	22	.....			
5	Aug. 6	Aug. 11	21	5	Aug. 14	16	3	Aug. 17	4	3	11	Sept. 8	2	2	22	33			
								Aug. 18	12	4	12	Sept. 8	1	.....	21	33			
												Sept. 9	3	4	22	34			
												Sept. 10	3	.....	23	35			
												Sept. 11	1	.....	24	36			
					Aug. 15	5	4	Aug. 18	2	3	12	Sept. 9	.....	2	22	34			
								Aug. 19	3	4	13	Sept. 9	1	.....	21	34			
												Sept. 10	1	1	22	35			
		Aug. 12	11	6	Aug. 15	8	3	Aug. 18	3	3	12	Sept. 10	3	.....	23	35			
								Aug. 19	4	4	13	Sept. 10	2	2	22	35			

[1] Not carried further.

TABLE VII.—*Developmental period of the cherry leaf-beetle exclusive of the incubation period, North East, Pa., 1915*—Continued.

Lot No.	Date hatched.	Date first molt.	Number of individuals.	First stage duration.	Date second molt.	Number of individuals.	Second stage duration.	Date in ground.	Number of individuals.	Feeding period, third stage.	Total feeding period.	Date adults emerged.	Number of—		Period in ground.	Period from hatching to emergence of adults.
													Male.	Female.		
				Days.			*Days.*			*Days.*	*Days.*				*Days.*	*Days.*
5					Aug. 16	3	4	Aug. 19	1	3	13	Sept. 10	.....	1	22	35
								Aug. 20	2	4	14	Sept. 10	1	.....	21	35
												Sept. 11	1	.....	23	36
		Aug. 13	2	7	Aug. 16	1	3	Aug. 21	1	5	15	Sept. 11	1	.....	21	36
					Aug. 17	1	4	Aug. 21	1	4	15	Sept. 11	1	.....	21	36
		Aug. 16	1	10	Aug. 21	1	5	Aug. 24	1	3	18	Sept. 14	1	.....	21	39
		Aug. 17	1	11	Aug. 21	1	4	Aug. 26	1	5	20	Sept. 15	1	.....	20	40
10	Aug. 7	Aug. 11	1	4	Aug. 15	1	4	Aug. 18	1	3	11	Sept. 10	1	.....	23	34
		Aug. 12	46	5	Aug. 15	41	3	Aug. 18	13	3	11	Sept. 9	3	2	22	33
												Sept. 10	5	1	23	34
												Sept. 11	1	.....	24	35
								Aug. 19	22	4	12	Sept. 10	4	10	22	34
												Sept. 11	3	4	23	35
												Sept. 12	.....	1	24	36
								Aug. 20	6	5	13	Sept. 10	2	.....	21	34
												Sept. 11	1	3	22	35
					Aug. 16	3	4	Aug. 19	3	3	12	Sept. 10	1	2	22	34
		Aug. 13	2	6	Aug. 16	2	3	Aug. 20	2	4	13	Sept. 12	½	1	23	36
		Aug. 14	1	7	Aug. 18	1	4	Aug. 23	1	5	16	Sept. 13	1	.....	21	37
14	Aug. 8	Aug. 12	22	4	Aug. 15	11	3	Aug. 18	3	3	10	Sept. 10	1	2	23	33
								Aug. 19	8	4	11	Sept. 9	.....	1	21	32
												Sept. 10	4	2	22	33
					Aug. 16	11	4	Aug. 9	3	3	11	Sept. 10	2	.....	22	33
												Sept. 11	.....	1	23	34
								Aug. 20	8	4	12	Sept. 10	4	1	21	33
												Sept. 11	1	.....	22	34
												Sept. 12	1	1	23	35
		Aug. 13	45	5	Aug. 16	36	3	Aug. 19	8	3	11	Sept. 10	2	5	22	33
								Aug. 20	27	4	12	Sept. 10	2	1	21	33
												Sept. 11	8	7	22	34
												Sept. 12	1	3	23	35
								Aug. 22	1	6	14	Sept. 12	1	1	21	35
					Aug. 17	9	4	Aug. 20	8	3	12	Sept. 12	2	6	23	35
		Aug. 14	2	6	Aug. 17	1	3	Aug. 21	1	4	13	Sept. 12	.....	1	22	35
					Aug. 18	1	4	Aug. 23	1	5	15	Sept. 13	.....	1	21	36
18	Aug. 11	Aug. 15	19	4	Aug. 18	14	3	Aug. 22	8	4	11	Sept. 12	2	5	21	32
								Aug. 23	6	5	12	Sept. 12	5	1	20	32
					Aug. 19	5	4	Aug. 23	3	4	12	Sept. 12	1	.....	20	32
												Sept. 13	.....	1	21	33
												Sept. 14	1	.....	22	34

								Aug. 24	2	5	13	Sept. 14	1	1	21	34
		Aug. 16	4	5	Aug. 19	4	3	Aug. 24	4	5	13	Sept. 13	.....	2	20	33
												Sept. 14	1	1	21	34
19	Aug. 12	Aug. 16	17	4	Aug. 19	5	3	Aug. 23	5	4	11	Sept. 12	1	.....	20	31
												Sept. 13	2	1	21	32
					Aug. 20	11	4	Aug. 24	10	4	12	Sept. 14	4	3	21	33
												Sept. 15	2	.....	22	34
		Aug. 17	10	5	Aug. 20	4	3	Aug. 24	4	4	12	Sept. 14	.....	1	21	33
												Sept. 15	2	1	22	34
					Aug. 21	4	4	Aug. 25	4	4	13	Sept. 14	1	1	20	33
												Sept. 16	.....	2	22	35
		Aug. 19	1	7	Aug. 24	1	5	Aug. 29	1	5	17	Sept. 18	.....	1	20	37
20	Aug. 13	Aug. 17	12	4	Aug. 21	10	4	Aug. 25	10	4	12	Sept. 14	.....	1	20	32
												Sept. 15	4	5	21	33
					Aug. 22	2	5	Aug. 26	2	4	13	Sept. 15	.....	1	20	33
												Sept. 16	1	.....	21	34
		Aug. 18	5	5	Aug. 22	1	4	Aug. 27	1	5	14	Sept. 16	1	.....	20	34
					Aug. 23	2	5	Aug. 28	2	5	15	Sept. 16	.....	2	19	34
					Aug. 24	1	6	Aug. 30	1	6	17	Sept. 17	.....	1	18	35
					Aug. 25	1	7	Sept. 2	1	8	20	Sept. 18	1	.....	16	36
21	Aug. 14	Aug. 18	7	4	Aug. 22	4	4	Aug. 26	4	4	12	Sept. 14	1	.....	19	31
												Sept. 15	2	1	20	32
					Aug. 23	3	5	Aug. 27	3	4	13	Sept. 15	.....	1	19	32
												Sept. 16	1	1	20	33
		Aug. 19	7	5	Aug. 23	7	4	Aug. 27	3	4	13	Sept. 15	1	1	19	32
												Sept. 16	.....	1	20	33
								Aug. 28	2	5	14	Sept. 16	1	1	19	33
								Aug. 29	2	6	15	Sept. 16	.....	2	18	33
22	Aug. 16	Aug. 21	2	5	Aug. 25	1	4	Aug. 30	1	5	14	Sept. 16	.....	1	17	31
					Aug. 26	1	5	Sept. 3	1	8	18	Sept. 18	.....	1	15	33
23	Aug. 17	Aug. 23	1	6	Aug. 28	1	5	Sept. 4	1	7	18	Sept. 18	.....	1	14	32
		Aug. 24	1	7	Aug. 28	1	4	Sept. 4	1	7	18	Sept. 18	1	.....	14	32
24	Aug. 18	Aug. 24	1	6	Aug. 29	1	5	Sept. 5	1	7	18	.....	.....	.....	.....	.....
Totals and weighted averages.....			242	4.83	.....	268	3.58	.....	349	4.12	12.33	.....	282	281	22.36	[1] 33.76

[1] Average period for 111 males and 107 females.

The proportion of sexes under natural conditions was not determined, but among those reared in the life-history cages the males and females appeared in almost exactly equal numbers, there being 282 males and 281 females.

SEASONAL-HISTORY SUMMARY.

The cherry leaf-beetle hibernates in the adult stage. The beetles emerge from their winter quarters in the late spring, and, after feeding for a few weeks and mating, the females go to the bases of the trees and deposit their eggs in the accumulation of rubbish. In something less than two weeks the eggs hatch. The larvæ grow rapidly and in less than two weeks attain full growth, when they burrow a short distance into the ground, pass through their pupal stage, and, in from two to three weeks after entering the ground, reappear as adult beetles. These beetles feed until cold weather compels them to seek shelter for the winter.

The season of 1915 was unusually cold and wet, and this condition undoubtedly delayed the development of the insect to a considerable extent. The hibernating beetles appeared at North East on June 7. Within two weeks their numbers were noticeably diminishing, but beetles of both sexes were observed as late as August 5, and females collected at this time still contained eggs. Unfortunately the natural food plant and egg-laying habits were not learned until the 3d of August, but at this time many eggs were still unhatched. Larvæ continued to emerge until August 14, and from another lot of eggs collected August 5 larvæ were hatched as late as August 18. At the time these eggs were collected there were full-grown larvæ on the trees, and many had undoubtedly entered the ground for pupation. Larvæ were observed on the pin cherry as late as September 10, when a full-grown larva and a young third-stage larva were found on some foliage that had been brought into the laboratory two days earlier. The active feeding portion of the larval life in the cages varied from 10 to 20 days, the average being 12.33 days.

The period spent in the ground in the cages varied from 14 to 28 days, the average being 22.36 days. The total developmental period is from 45 to 50 days.

The earliest adult to emerge in the cages appeared on August 23, but the pale, newly emerged beetles were observed in the open on the 16th. On August 31 the adults of the new brood were abundant on pin cherry, while many young beetles and pupæ and a few larvæ were found in soil and leaf mold under the bushes. On September 8 adults were abundant, but by September 23 they had begun to disappear, and no pupæ could be found in the ground, although a few newly emerged adults were observed.

A PREDATORY ENEMY.

In the leaf mold at the base of wild cherry trees, in which cherry leaf-beetles were transforming in great numbers, small carabid beetles with a striking color pattern of black and yellow were also abundant. These beetles were determined by Mr. E. A. Schwarz to be a large form of *Lebia ornata* Say. (Fig. 9.) In confinement these carabids would eat pupæ and callow adults voraciously. In attacking an adult Galerucella the carabid would tear off one elytron and then eat the soft body tissues. In confinement one Lebia killed four callow Galerucella adults in one night; only one was eaten, but the others all had the wings on one side torn off and were more or less mutilated otherwise. When pupæ were killed nothing was left but the pupal skin.

Several other carabids were found in places where the cherry leaf-beetle transforms, but none was found feeding upon it, nor could any of them be induced to do so in confinement.

FIG. 9.—*Lebia ornata*, a predatory enemy of the cherry leaf-beetle. Much enlarged. (Original.)

CONTROL.

PREVIOUS RECOMMENDATIONS.

There is no indication from entomological literature that any experiments to control this beetle have been conducted previous to 1915. Pettit (1898), Chittenden (1899), and O'Kane (1914) have recommended the use of Paris green and other arsenicals, doubtless basing their recommendations on their knowledge of related insects. Pettit (1898) recommended also the use of soap solution and kerosene emulsion, if spraying must be done on the trees when fruit is ripening.

EXPERIMENTS IN 1915.

When the cherry leaf-beetle appeared in the vicinity of North East, experimental spraying against the grape-berry moth was in progress at this station. Consequently no experimental work to control the beetle was undertaken until four days later, when the work in hand was finished. The effectiveness of poisoned sprays in these experiments was lessened somewhat by the fact that the beetles were feeding less heavily at the time of the application than they had been immediately after their arrival in this region.

All spraying experiments made against beetles of the spring migration were in two small orchards belonging to the late J. L. Spofford and M. D. Phillips, except some small cage experiments which were conducted in the insectary yard. These two orchards adjoined each other and were alike in so many ways that they were treated as

one orchard. The trees were 4 years old and of Early Richmond and Montmorency varieties. The former variety was used almost exclusively in the experiments.

Arsenate of Lead.

KILLING STRENGTH.

In order to determine the amount of poison necessary to kill the cherry leaf-beetle, trees were sprayed with various strengths of arsenate of lead on June 11. Two, 3, 4, 5, and 6 pounds were used to 50 gallons of water; one-half pound of lime was added to each of these mixtures. In addition mixtures at the rate of 3 pounds to 50 gallons and 5 pounds to 50 gallons, to which had been added 1½ gallons of molasses, were applied. To supplement the conclusions on the effect of the various mixtures drawn from observation of the beetles on the trees sprayed, about 100 beetles were confined in a bag on a branch of one tree sprayed by each of the different mixtures. No burning of foliage followed the application of any of the solutions used.

The various arsenate of lead and lime mixtures were ineffective in killing many of the beetles. The stronger solutions—4, 5, and 6 pounds to 50 gallons—were repellent and consequently to an extent protected the trees. The weaker solutions—2 and 3 pounds to 50 gallons—were ineffective even as repellents, for the beetles confined in bags on trees thus sprayed fed without apparent inconvenience. The beetles confined in bags on the trees sprayed with the stronger solutions, especially 5 and 6 pounds to 50 gallons, fed but little, although they were confined for a week. A negligible number of beetles, never 10 per cent, was found dead in the bags.

The sweetened arsenate of lead used at the rate of 3 pounds to 50 gallons was comparatively effective, although far from satisfactory. There were some dead beetles on the ground, and 40 per cent of those in the bag were dead. There was a good deal of feeding on the tree.

The sweetened arsenate of lead applied at the rate of 5 pounds to 50 gallons was effective. There were many dead beetles on the ground under the trees, and of the beetles in the bag 96 per cent were dead when examination was made three days after spraying. The trees sprayed with this mixture were effectively protected from injury.

On June 14 a tree that had been sprayed with 2 pounds of arsenate of lead to 50 gallons three days previous was resprayed with the same mixture to test the effectiveness of a double spray with a weak solution. The application was ineffective.

A second comparison of the sweetened and unsweetened mixtures of arsenate of lead was made June 19. The only strength of poison used was 5 pounds to 50 gallons of water, the weakest solution

effective in the first experiment. No lime was added to the unsweetened mixture and the molasses was used at the same rate as formerly, viz, 1½ gallons to 50 gallons of water.

Dead beetles were found under all the trees sprayed, but they were far more numerous under the trees sprayed with the sweetened mixture than under those sprayed with the unsweetened mixture. Also there was less feeding on the trees sprayed with the sweetened arsenate, although there was comparatively little on either, while the unsprayed check was loaded with beetles.

EFFECT OF LIME IN COMBINATION WITH ARSENATE OF LEAD.

To test the effect of lime as a repellent when used in sprays in combination with arsenate of lead, beetles were caged on parts of a tree in the insectary yard sprayed with lime water at the rate of 1 pound to 50 gallons and 5 pounds to 50 gallons. In both cages the beetles fed as freely on the leaves thus sprayed as on those that had not been sprayed.

Contact Sprays.

SOAP-CARBOLIC ACID SOLUTION.

A solution of fish-oil soap, 10 pounds to 50 gallons of water, to which three-fourths of a pint of carbolic acid was added, was tried as a contact spray on June 11. Immediately upon the application of this solution the majority of the beetles fell from the tree, apparently dead. Several hundred of these were gathered from the ground, placed in vials, and taken to the insectary. By the evening of the next day practically all of the beetles were active again and apparently uninjured by the spray. The solution is not permanently repellent, for the trees thus sprayed were badly attacked again two days after the application of the spray. This spray was not injurious to foliage.

NICOTINE SULPHATE.

A solution of 40 per cent nicotine sulphate at the rate of 1 part to 600 parts of water, to which was added fish-oil soap at the rate of 2 pounds to 50 gallons of liquid, was used as a contact spray on June 11. The effect was apparently similar to that of the soap-carbolic acid solution; some of the beetles escaped by flight but the majority fell from the tree when hit by the spray and soon appeared dead. Several hundred of them were gathered and taken to the insectary to test the permanence of this state. They were kept under observation for five days without showing any signs of life.

In order to compare the effectiveness of nicotine sulphate without soap, a large tree in the insectary yard was sprayed with nicotine

sulphate (40 per cent) on June 27. Of the beetles that fell from the tree, 318 were collected on a sheet and placed in a ventilated cage in the insectary. Five days later practically all of them, over 98 per cent, still showed no signs of life.

Weaker dilutions of 40 per cent nicotine sulphate were tested on September 9 on beetles of the new brood. Pin-cherry trees were sprayed, because at this time the beetles were feeding on no other. The following strengths were used: One part of nicotine sulphate to 800, 1,000, and 1,200 parts of water, respectively. Soap was added as in the first experiment at the rate of 2 pounds to 50 gallons of liquid. None of these strengths was effective, and none of them showed the immediate effects that followed spraying with a solution at the strength of 1 to 600. Many of the beetles hit with the sprays of the strengths of 1 to 800 and 1 to 1,000 became very sluggish and in 10 or 15 minutes appeared dead. Very few of those hit by the 1 to 1,200 solution appeared injured at all. About 150 beetles were collected from trees sprayed with each solution and placed in jars in the insectary. On the evening of September 10, 60 per cent of the beetles sprayed with the 1 to 800 solution, 68 per cent of those sprayed with the 1 to 1,000 solution, and 96 per cent of those sprayed with the 1 to 1,200 solution were active and feeding.

Results from Spraying by Growers.

Immediately following the advent of the cherry leaf-beetle in the Lake Erie grape belt there was unusual spraying activity to check it. Arsenate of lead was used in most instances, but applications of lime-sulphur, Bordeaux mixture, nicotine sulphate, soap, and lime, used in various combinations and at various strengths, were also made. The results were various.

Orchards in which arsenate of lead had been used at the rate of 5 pounds to 50 gallons of water, with and without lime, were observed by the writers. In these orchards the trees were generally quite well protected, although few dead beetles were found on the ground under the trees. Where weaker solutions of poison were used the results were far from satisfactory in the orchards observed. The use of sweetened arsenate of lead was observed in only one orchard outside of the experimental plats, and in this instance it was entirely unsuccessful. The spray was applied immediately before a heavy rain, which washed it all off.

A number of combination sprays in which 40 per cent nicotine sulphate was used were successful. The nicotine sulphate was sometimes used at rates as strong as 1 to 400. The following is a typical effective mixture: Arsenate of lead, 3 pounds; 40 per cent nicotine sulphate, 1 pound; laundry soap, 2 bars; water, 50 gallons.

Hydrated lime, dusted on trees by hand, was used as a protective measure, and in some instances appeared to be effective.

Summary of Experiments.

From the experiments and observations described, the following conclusions may be drawn:

Arsenate of lead must be used at a rate of not less than 5 pounds to 50 gallons of water to be effective in protecting trees from injury by the cherry leaf-beetle. A mixture to which molasses was added at the rate of 1½ gallons to 50 gallons of the mixture was effective in killing practically all of the beetles which fed upon the trees on which this mixture was applied. This addition of sweetening to the arsenate has the serious disadvantage of making the spray easily washed off by rains. Arsenate of lead used without molasses was less effective in protecting the trees, although it killed some beetles and it was to an extent repellent to them. Lime in the amount in which it is added to an arsenate-of-lead spray was not repellent.

Forty per cent nicotine sulphate applied with water at the rate of 1 to 600, with or without soap, was effective as a contact spray. Weaker dilutions of nicotine sulphate and soap-carbolic acid solutions, although apparently effective at the time of application, did not have a permanent effect.

CONTROL OF LARVÆ.

If the larvæ fed on a cultivated plant, control measures might be directed against it, thus preventing the adults from developing in destructive numbers. But it feeds on a wild plant that is usually present where control measures can not be applied, often on land that is in no way controlled by the fruit grower, and not even in the immediate vicinity of fruit farms. Nevertheless the clearing up of cut-over timberland and the destruction of the wild hosts of the larva of this beetle would greatly limit its possibilities of destructiveness. Should the cherry leaf-beetle become a permanent pest, cooperative work along this line might be advisable.

RECOMMENDATIONS.

Spray practice for the control of the cherry leaf-beetle at the time of its next appearance in economic numbers can not be absolutely determined from the foregoing experiments. The numbers of the beetles, the duration of the migration, and the weather conditions at the time must qualify any recommendation. More extensive experiments also might modify the results.

Nicotine sulphate, while temporarily effective, does not prevent a new invasion of an orchard on the day following its application. However, its use in peach orchards is recommended, for the greater

strengths of arsenate of lead would be likely to cause severe injury to peach foliage. The addition of 2 pounds of soft soap or 1 pound of hard soap to 50 gallons of the mixture has been generally found to increase the effectiveness of the nicotine sulphate.

Sweetened arsenate of lead is recommended for cherry trees because of its efficiency in killing the beetles and because its effect is continuous in favorable weather. Rain destroys the effectiveness of this spray. The combination found most useful is 5 pounds of arsenate of lead, 1½ gallons of molasses, and 50 gallons of water.

If the beetle migration should occur during a rainy period, the unsweetened arsenate of lead might be most useful.

In applying a poison spray care must be taken to cover the underside of the leaves where the beetles feed. In some instances it may be necessary to spray only young cherry trees or older trees of the thin-leaved varieties. In large orchards into which the beetles are migrating in great numbers it is advisable to spray first the trees most susceptible to attack, for during the season of 1915 the maximum injury occurred immediately after the first arrival of the beetles. In no case should the sweetened arsenate of lead be used with Bordeaux mixture as a combination spray, for burning of foliage is likely to result.

BIBLIOGRAPHY.

1865. LeConte, J. L. On the species of Galeruca and allied genera inhabiting North America. *In* Proc. Acad. Nat. Sci. Phila., p. 204–222.

Page 216. *Galeruca cavicollis*. Original description in Latin.

1890. Packard, A. S. Insects Injurious to Forest and Shade Trees. Fifth Rpt. U. S. Ent. Com., 957 p., 50 pl., 306 fig.

Page 529. *Galeruca sanguinea* observed in great abundance at Berlin Falls, N. H., Sept. 13, eating holes in leaves of wild cherry. Brief description of beetle.

1891. Schwarz, E. A. *Galeruca sanguinea*. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 4, nos. 3 and 4, p. 94.

Correction of name used by Packard (1890). "Common northern species."

1893. Horn, G. H. The Galerucini of boreal America. *In* Trans. Amer. Ent. Soc., v. 20, p. 57–144, pl. 1.

Pages 76–77. *Galerucella cavicollis* Lec. Description in English. "Occurs from Canada to the New England and Middle States westward to Wisconsin; North Carolina (Lec.)."

1894. Davis, G. C. Report of the consulting entomologist. *In* 7th Ann. Rpt. Expt. Sta. State Agr. Col. Mich., p. 85–93, 5 fig.

Page 93. *Adimonia cavicollis*.

1894. Davis, G. C. Special insects of the year. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 7, no. 2, p. 198–201.

Page 200. *Adimonia cavicollis* recorded as injuring cultivated cherry at Bellaire, Mich. First record of injury to cultivated cherry.

1895. Hamilton, John. Catalog of the Coleoptera of Southwestern Pennsylvania, with notes and descriptions. *In* Trans. Amer. Ent. Soc., v. 22, p. 317–381.

Page 371. *Galerucella cavicollis* mentioned as rare in southwestern Pennsylvania.

1896. Davis, G. C. Report of the consulting entomologist. *In* 9th Ann. Rpt. Expt. Sta. State Agr. Col. Mich., p. 135–138.

Page 136. *Adimonia cavicollis* attacking, in addition to cherry, apple, peach, and plum. Arsenites reported as of little value for control.

1896. Lintner, J. A. *Galerucella cavicollis* Lec. *In* 11th Report on the Injurious and Other Insects of the State of New York f. 1895, p. 197–198.

Recorded as feeding on the foliage of cultivated cherry and as taken on chestnut at Au Sable Forks, N. Y. Quotes Davis, Packard, and others.

1897. Johnson, C. W. Report on insects injurious to the spruce and other forest trees. *In* 3rd Ann. Rpt. Penn. Agr. Dept., Pt. II, p. 69–110, 6 pl., 11 fig.

Pages 106–107. *Galerucella cavicollis*, beetles and larvæ feeding in myriads on leaves of "fire cherry" first week of September in Wyoming Co., Pa.

1898. Barrows, W. B., and Pettit, R. H. Some insects of the year 1897. *In* 37th Ann. Rpt. Mich. State Bd. Agr. f. 1897–1898, p. 565–602.

Pages 593–594. *Galerucella cavicollis* Lec. Comments on change from wild food plants to cultivated trees. Quotes Davis. Life cycle. Recommends Paris green, fish-oil soap, and kerosene emulsion.

1898. Felt, E. P. *Galerucella cavicollis* Lec. *In* Bul. N. Y. State Mus., v. 5, no. 23 (14th Rpt. State Ent. N. Y.), p. 235.

Records injury to cherry at Corning, N. Y. Quotes Lintner.

1898. FELT, E. P. Notes on some of the insects of the year in the State of New York. *In* U. S. Dept. Agr. Div. Ent. Bul. 17, n. s., p. 16–23.

Repetition of foregoing.

1898. SMITH, J. B. *Galerucella cavicollis*. *In* U. S. Dept. Agr. Div. Ent. Bul. 17, n. s., p. 23.

Records finding species on peach in Pennsylvania.

1899. CHITTENDEN, F. H. The cherry leaf-beetle (*Galerucella cavicollis* Lec.). *In* U. S. Dept. Agr. Div. Ent. Bul. 19, n. s., p. 90–93.

Only long article on this species. Summarizes previous accounts and records injury to cherry at St. Ignace, Mackinac Co., Mich., and to peach at Spruce Creek, Huntington Co., Pa., and at Lebanon, Lebanon Co., Pa., in 1898. Distribution. Description of egg and incubation period. Arsenical spray, as described for use against the leaf-beetle, recommended.

1899. LUGGER, OTTO. Fifth Ann. Rpt. Ent. State Expt. Sta. Univ. Minn. f. 1899, 248 p., 6 pl., 249 fig.

Pages 152–154. The cherry leaf-beetle, *Adimonia femoralis* Melsh. Native plum and "fire cherry" (*Prunus pennsylvanica*) as natural food plants. Descriptions of adults, egg, and larva. Life cycle.

1900. HARVEY, F. L. Notes on insects of the year 1899. *In* Maine Agr. Expt. Sta. Bul. 60, p. 31–36.

Page 35. *Adimonia cavicollis*. Reports injury to cherry in vicinity of Orono, Me.

1901. PETTIT, R. H. Insect and animal life on the Upper Peninsula Experiment Station. *In* 40th Ann. Rpt. State Bd. Agr. Mich., p. 184–195, 7 fig.

Page 192. *Galerucella cavicollis* Lec. Mentions "pin cherry" as natural food plant. Cites two occasions when it attacked cultivated cherry in Michigan, quoting Davis (1894) and Pettit (1897). Paris green effective remedy.

1903. WASHBURN, F. L. Injurious insects of 1903. Univ. Minn. Agr. Expt. Sta. Bul. 84, 184 p., 1 pl., 119 fig.

Page 96. *Galerucella cavicollis* Lec. Brief mention in list of cherry insects with recommendation of "arsenical sprays if any remedy should be called for."

1905. PETTIT. R. H. Insects injurious to the apple. Special Bulletin No. 24. *In* 44th Ann. Rpt. State Bd. Agr. Mich., p. 287–346, 70 fig.

Pages 312–313. *Galerucella cavicollis*. Natural food plant, pin cherry. Hibernation and habits of hibernated beetles. Larva also works on foliage.

1906. FELT, E. P. Insects Affecting Park and Woodland Trees. Memoir 8, N. Y. State Mus., 877 p., 70 pl., 223 fig. Albany.

Page 550. *Galerucella cavicollis* Lec. abundant on wild cherry in Adirondacks in August, 1900. Quotes Lintner.

1909. SMITH, J. B. Report of the New Jersey State Museum f. 1909. The Insects of New Jersey, 888 p., 340 fig. Trenton.

Page 347. *Galerucella cavicollis* Lec. feeds on peach, plum, and cherry.

1910. BLATCHLEY, W. S. Coleoptera of Indiana. 1386 p., 590 fig. Indianapolis.

Page 1169. *Galerucella cavicollis* Lec. Description of adult. Distribution.

1911. GOSSARD, H. A. *Galerucella cavicollis*. *In* Ohio Agr. Expt. Bul. 233, p. 129.

Recorded as occurring in September. Control spray of arsenate of lead, 3 to 5 pounds to 50 gallons of water.

1914. O'KANE, W. C. Injurious Insects, 414 p., 606 fig. New York.

Page 263. *Galerucella cavicollis* Lec. feeds on cherry, plum, and peach. Larvæ also feed on the leaves. Pupal stage in ground. Two broods annually. Arsenate of lead or Paris green recommended.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO DECIDUOUS FRUITS.

AVAILABLE FOR FREE DISTRIBUTION.

Insect and Fungous Enemies of the Grape East of the Rocky Mountains. (Farmers' Bulletin 284.)
Spraying Peaches for the Control of Brown Rot, Scab, and Curculio. (Farmers' Bulletin 440.)
The More Important Insect and Fungous Enemies of the Fruit and Foliage of the Apple. (Farmers' Bulletin 492.)
The Gipsy Moth and the Brown-tail Moth, with suggestions for Their Control. (Farmers' Bulletin 564.)
The San Jose Scale and Its Control. (Farmers' Bulletin 650.)
The Apple-Tree Tent Caterpillar. (Farmers' Bulletin 662.)
The Round-headed Apple-tree Borer. (Farmers' Bulletin 675.)
Grape Leafhopper in Lake Erie Valley. (Department Bulletin 19.)
Control of Codling Moth in Pecos Valley, N. Mex. (Department Bulletin 88.)
Walnut Aphides in California. (Department Bulletin 100.)
The Lesser Bud-Moth. (Department Bulletin 113.)
The Life History and Habits of the Pear Thrips in California. (Department Bulletin 173.)
Studies of the Codling Moth in the Central Appalachian Region. (Department Bulletin 189.)
The Cranberry Rootworm. (Department Bulletin 263.)
Pear-tree Psylla. (Entomology Circular 7.)
Buffalo Tree-hopper. (Entomology Circular 23.)
Boxelder Plant-bug. (Entomology Circular 28.)
Larger Apple-tree Borers. (Entomology Circular 32.)
Apple Maggot or Railroad Worm. (Entomology Circular 101.)
Oyster-shell Scale and Scurfy Scale. (Entomology Circular 121.)
San Jose Scale and Its Control. (Entomology Circular 124.)
How to Control Pear Thrips. (Entomology Circular 131.)
One-spray Method in Control of Codling Moth and Plum Curculio. (Entomology Bulletin 80, pt. VII, revised.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

Homemade Lime-sulphur Concentrate. (Department Bulletin 197.) Price, 5 cents.
Life History of the Codling Moth in Maine. (Entomology Bulletin 252.) Price, 10 cents.
American Plum Borer. (Department Bulletin 261.) Price, 5 cents.
The Parandra Borer. (Department Bulletin 262.) Price, 5 cents.
Miscellaneous Insecticide Investigations. (Department Bulletin 278.) Price, 10 cents.
Canker-worms. (Entomology Circular 9.) Price, 5 cents.
Woolly Aphis of Apple. (Entomology Circular 20.) Price, 5 cents.
Pear Slug. (Entomology Circular 26.) Price, 5 cents.
Fruit-tree Bark-beetle. (Entomology Circular 29.) Price, 5 cents.
Peach-tree Borer. (Entomology Circular 54.) Price, 5 cents.
Plum Curculio. (Entomology Circular 73.) Price, 5 cents.
Aphides Affecting Apple. (Entomology Circular 81.) Price, 5 cents.

Terrapin Scale. (Entomology Circular 88.) Price, 5 cents.
Nut Weevils. (Entomology Circular 99.) Price, 5 cents.
Leaf Blister Mite. (Entomology Circular 154.) Price, 5 cents.
San Jose or Chinese Scale. (Entomology Bulletin 62.) Price, 25 cents.
Pecan Cigar Case-bearer. (Entomology Bulletin 64, part 10.) Price, 5 cents.
Papers on Deciduous Fruit Insects and Insecticides. (Entomology Bulletin 68, 9 parts.) Price, 25 cents.
Spring Canker-Worm. (Entomology Bulletin 68, part 2.) Price, 5 cents.
Trumpet Leaf-Miner of Apple. (Entomology Bulletin 68, part 3.) Price, 5 cents.
Lesser Peach Borer. (Entomology Bulletin 68, part 4.) Price, 5 cents.
Lesser Apple Worm. (Entomology Bulletin 68, part 5.) Price, 5 cents.
Demonstration Spraying for Codling Moth. (Entomology Bulletin 68, part 7.) Price, 5 cents.
Grape-leaf Skeletonizer. (Entomology Bulletin 68, part 8.) Price, 5 cents.
Peach-tree Barkbeetle. (Entomology Bulletin 68, part 9.) Price, 5 cents.
Periodical Cicada. (Entomology Bulletin 71.) Price, 40 cents.
Codling Moth in the Ozarks. (Entomology Bulletin 80, part 1.) Price, 10 cents.
Cigar Case-bearer. (Entomology Bulletin 80, part 2.) Price, 10 cents.
Additional Observations on the Lesser Apple Worm. (Entomology Bulletin 80, part 3.) Price, 5 cents.
On Nut-feeding Habits of Codling Moth. (Entomology Bulletin 80, part 5.) Price, 5 cents.
Life History of Codling Moth in Northwestern Pennsylvania. (Entomology Bulletin 80, part 6.) Price, 10 cents.
Fumigation of Apples for San Jose Scale. (Entomology Bulletin 84.) Price, 20 cents.
Grape Root-worm, with Especial Reference to Investigations in Erie Grape Belt, 1907 to 1909. (Entomology Bulletin 89.) Price, 20 cents.
Papers on Deciduous Fruit Insects and Insecticides. (Entomology Bulletin 97, 7 parts.) Price, 25 cents.
Life History of Codling Moth and Its Control on Pears in California. (Entomology Bulletin 97, part 2.) Price, 10 cents.
Vineyard Spraying Experiments Against Rosechafer in Lake Erie Valley. (Entomology Bulletin 97, part 3.) Price, 5 cents.
California Peach Borer. (Entomology Bulletin 97, part 4.) Price, 10 cents.
Notes on Peach and Plum Slug. (Entomology Bulletin 97, part 5.) Price, 5 cents.
Notes on Peach Bud Mite, Enemy of Peach Nursery Stock. (Entomology Bulletin 97, part 6.) Price, 10 cents.
Grape Scale. (Entomology Bulletin 97, part 7.) Price, 5 cents.
Plum Curculio. (Entomology Bulletin 103.) Price, 50 cents.
Life-history Studies on Codling Moth in Michigan. (Entomology Bulletin 115, part 1.) Price, 15 cents.
One-spray Method in Control of Codling Moth and Plum Curculio. (Entomology Bulletin 115, part 2.) Price, 5 cents.
Life History of Codling Moth in Santa Clara Valley of California. (Entomology Bulletin 115, part 3.) Price, 10 cents.
Grape-berry Moth. (Entomology Bulletin 116, part 2.) Price, 15 cents.
Cherry Fruit Sawfly. (Entomology Bulletin 116, part 3.) Price, 5 cents.
Lime-sulphur as Stomach Poison for Insects. (Entomology Bulletin 116, part 4.) Price, 5 cents.
Fruit-tree Leaf-roller. (Entomology Bulletin 116, part 5.) Price, 10 cents.
Insects Injurious in Cranberry Culture. (Farmers' Bulletin 178.) Price, 5 cents.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916